A Novel TiO_x Protection Film for Organic Solar Cells

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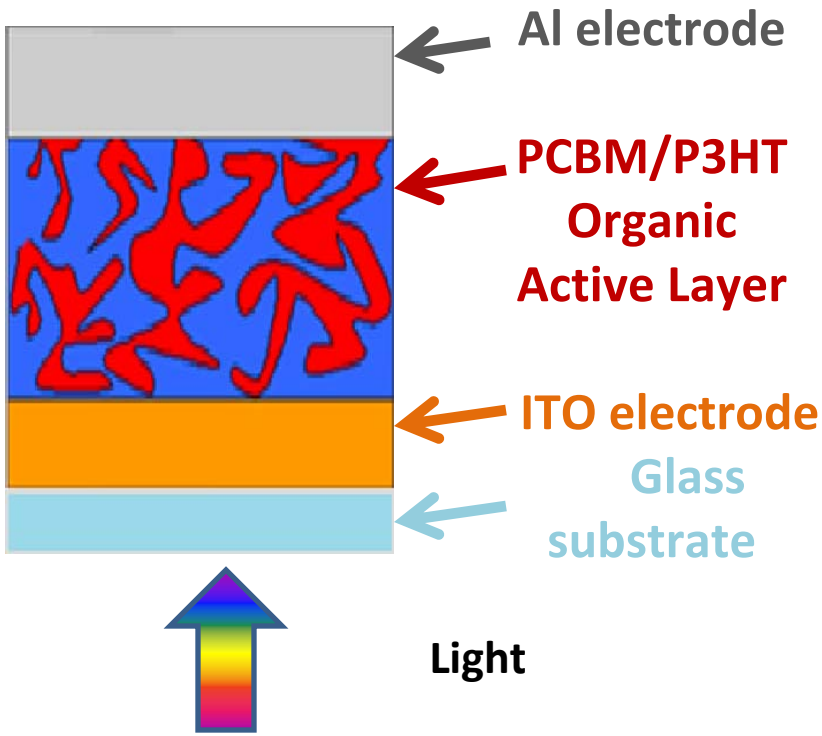
Organic Solar Cells

- Advantages
  - –Low cost
  - –Solution processable
  - –Light weight
  - –Flexible geometry

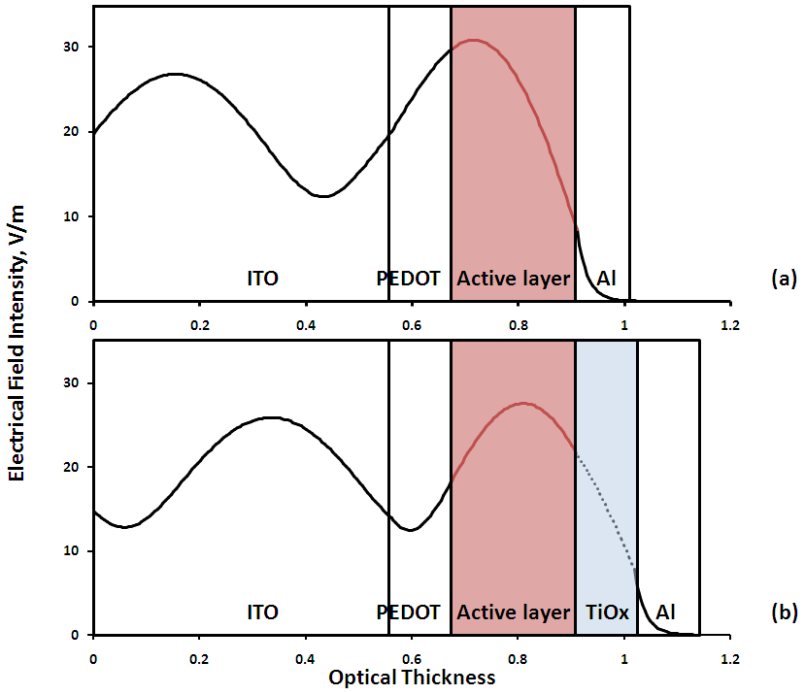


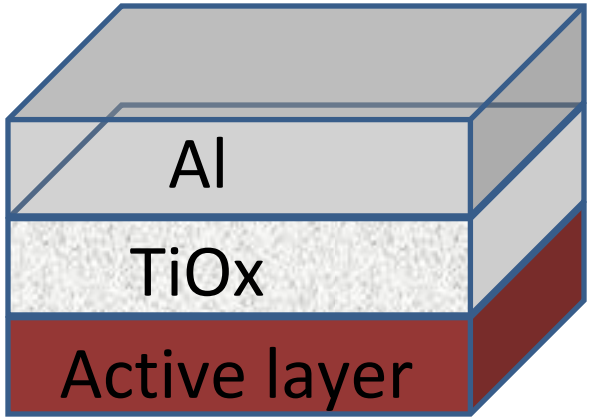
Issues with Organic Solar Cells

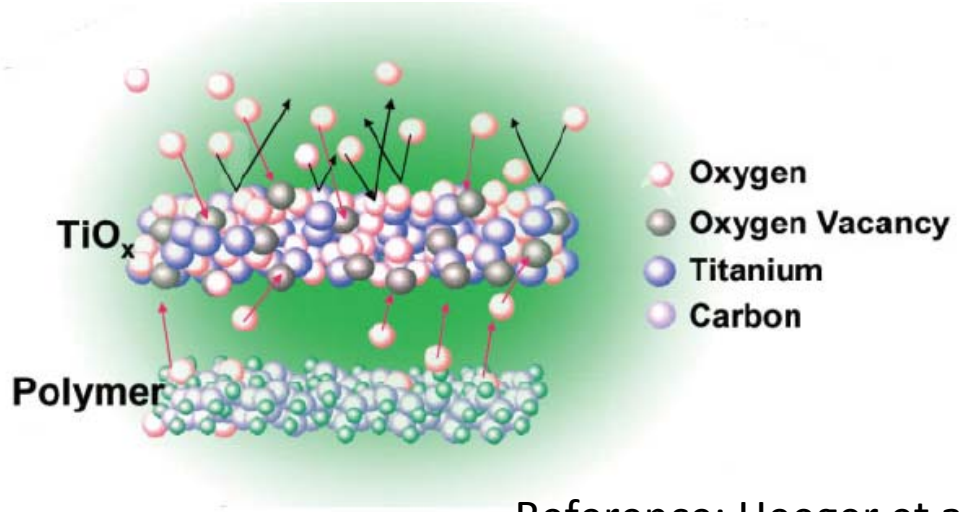
- Low efficiency
- Poor long-term stability, short life time

Previous Work

- Thin film of TiO_x
  - Enhanced efficiency due to optical spacer
  - Extended lifetime
  - Mechanism is unclear



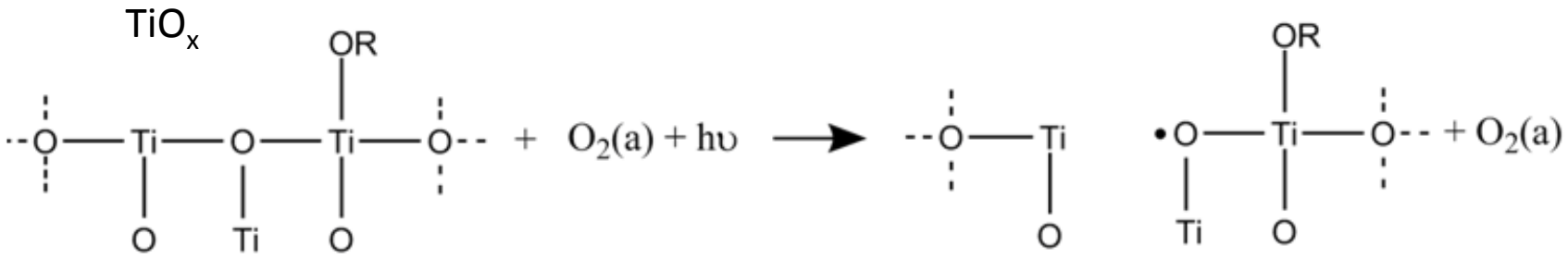




Reference: Heeger et al.

Mechanism Study: Photoactivation of TiO_x

- Photoactivation of TiO_x proposed by Yates' group
  - UV Light exposure in the presence of O_2(gas) produces electron-hole pairs which evolve to produce adsorbed O_2^-. The production of O_2^- from adsorbed O_2 is coupled to O^- hole stabilization and subsequent oxidation of the alkoxide moiety.



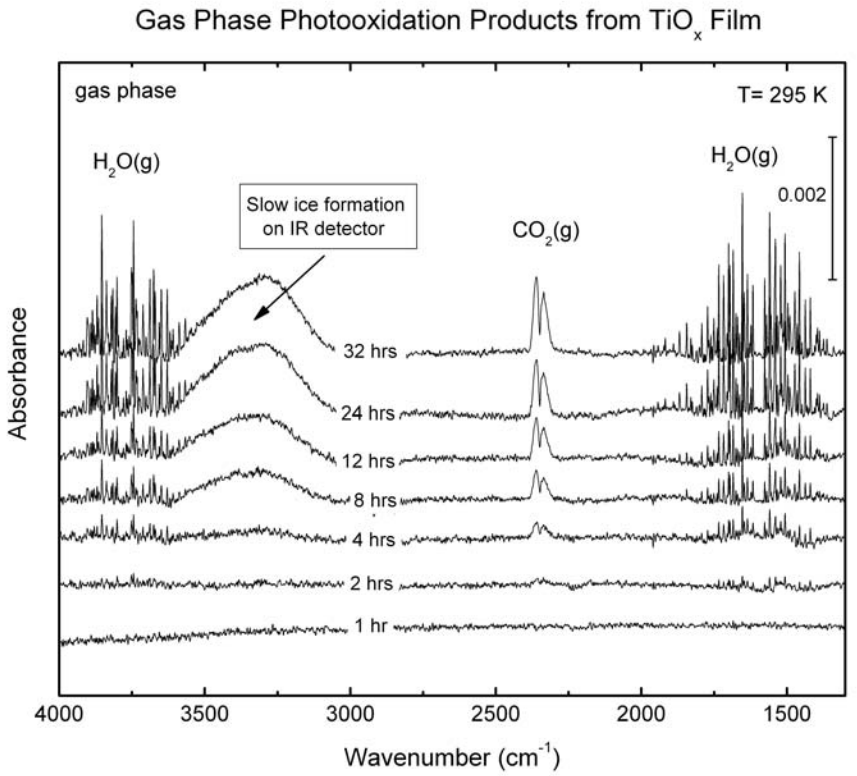
Reference: S. H. Kim et al

Mechanism Study: Protection Mechanism

- Mechanism
  - Ti-OR functionalities in TiO_x and Ti-OH groups are photooxidized, consuming O_2(gas) and producing CO_2(gas) and H_2O(gas). The photoactivation of these films leads to O_2 scavenging and forms the basis for thin films which remove oxygen when exposed to light,

Mechanism Study

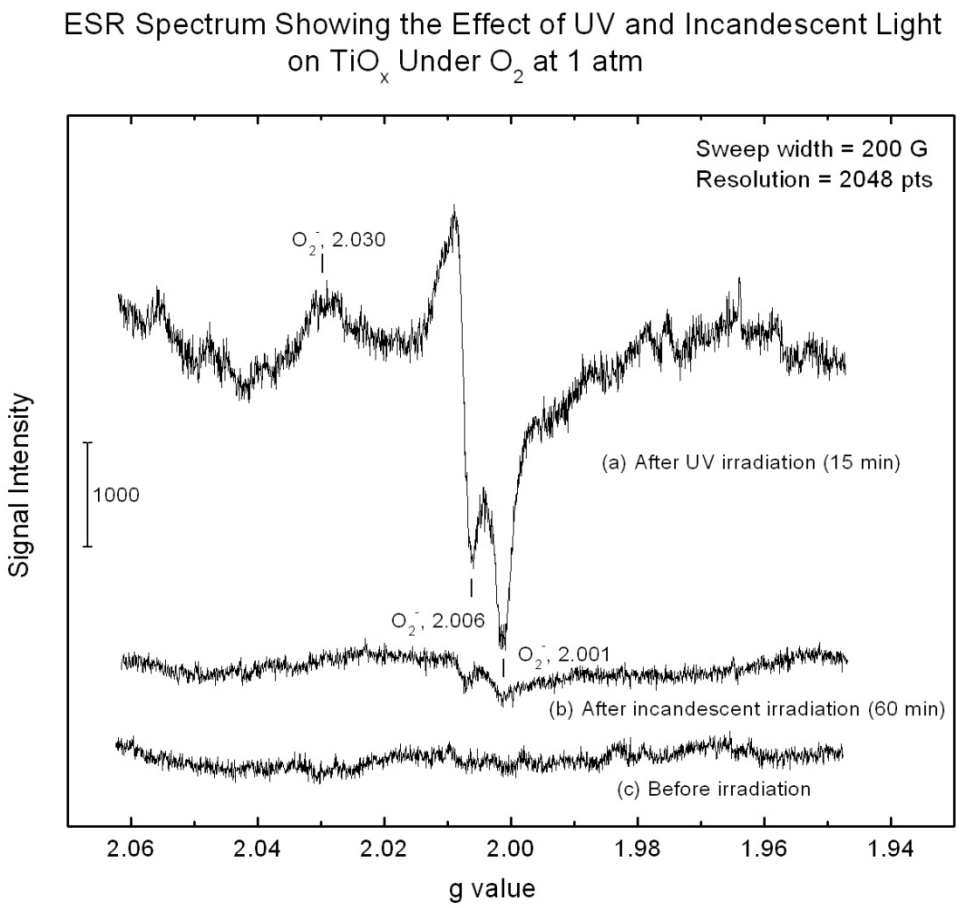
- IR spectrum
  - Gas phase photooxidation products from TiO_x film containing isopropoxide functionalities. CO_2 (gas) and H_2O(gas) are observed



Reference: S. H. Kim et al

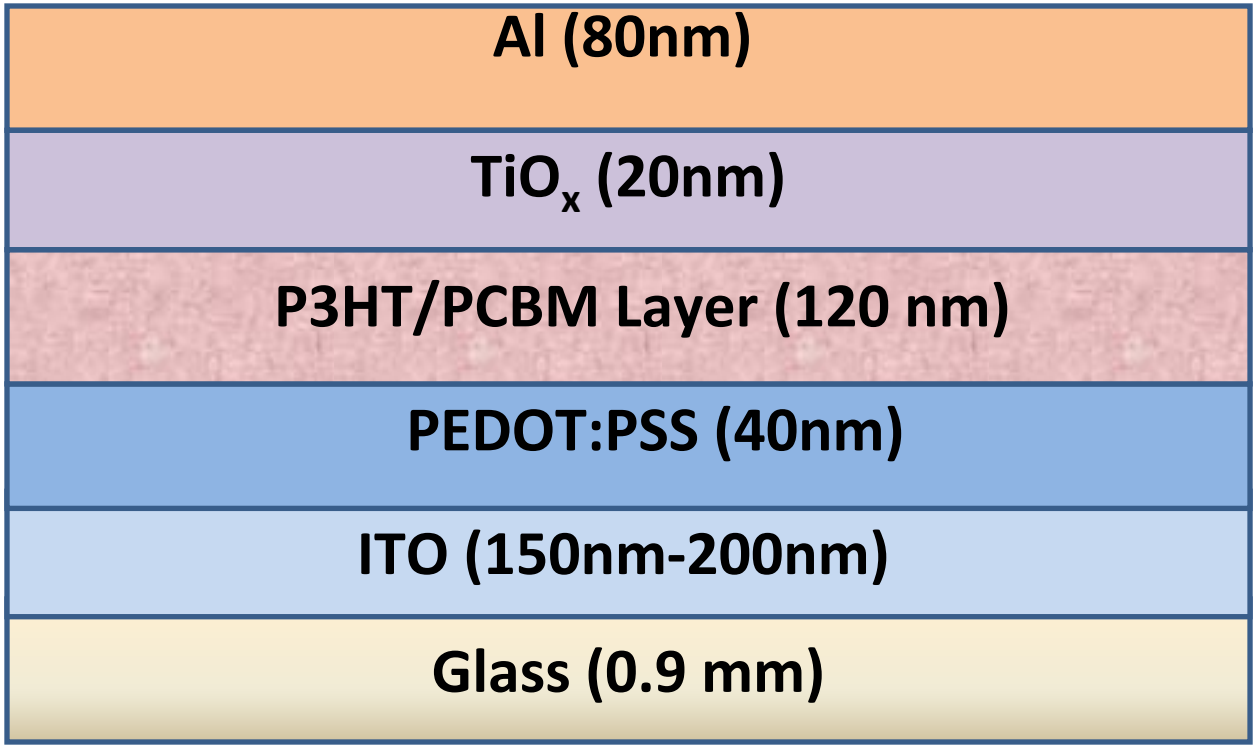
Mechanism Study

- ESR spectrum after photooxidation
  - After exposure to UV irradiation for 15 minutes, three strong ESR features are observed. The three ESR transitions are assigned to adsorbed O2-



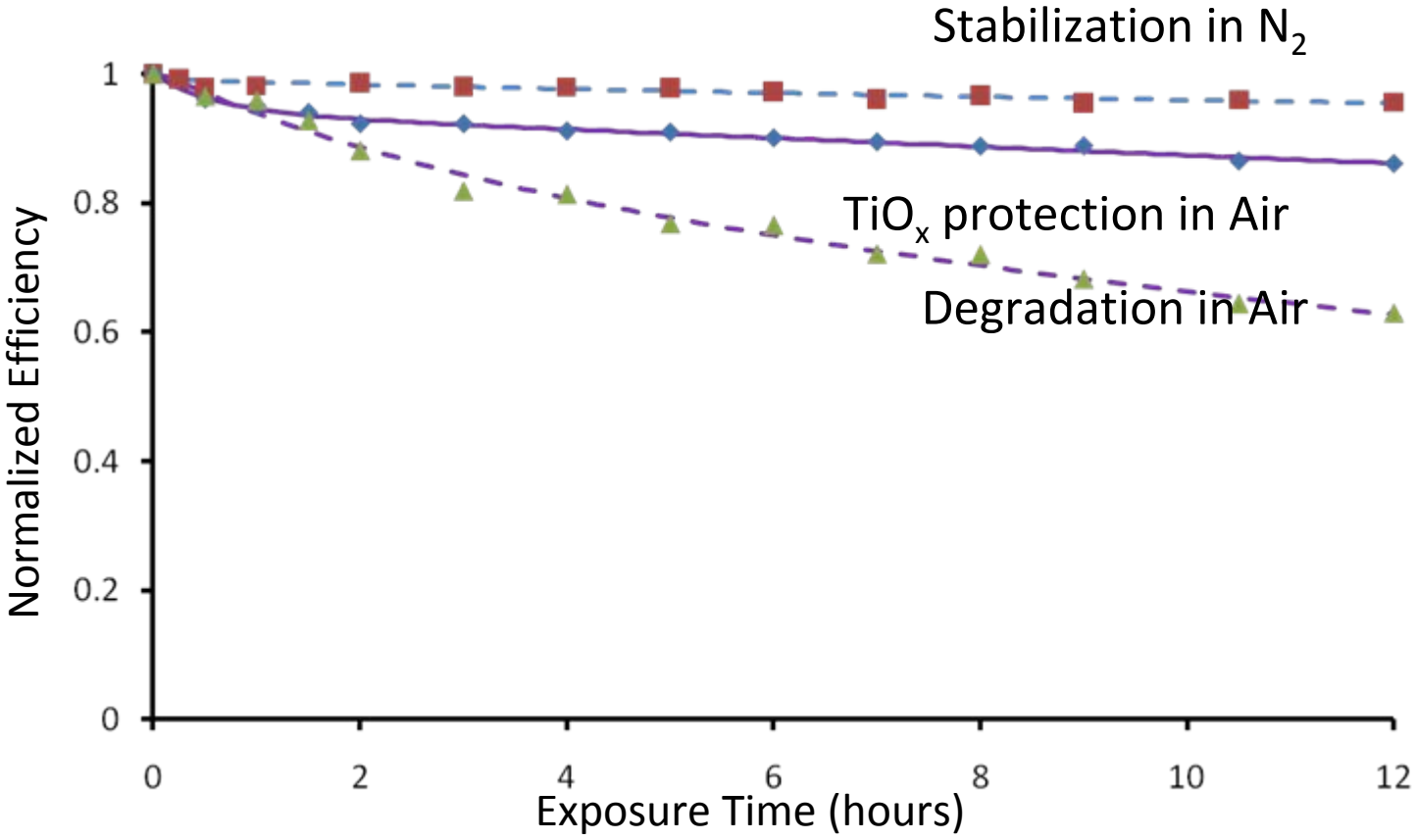
Reference: S. H. Kim et al

Photovoltaic Device Structure



Degradation in dark

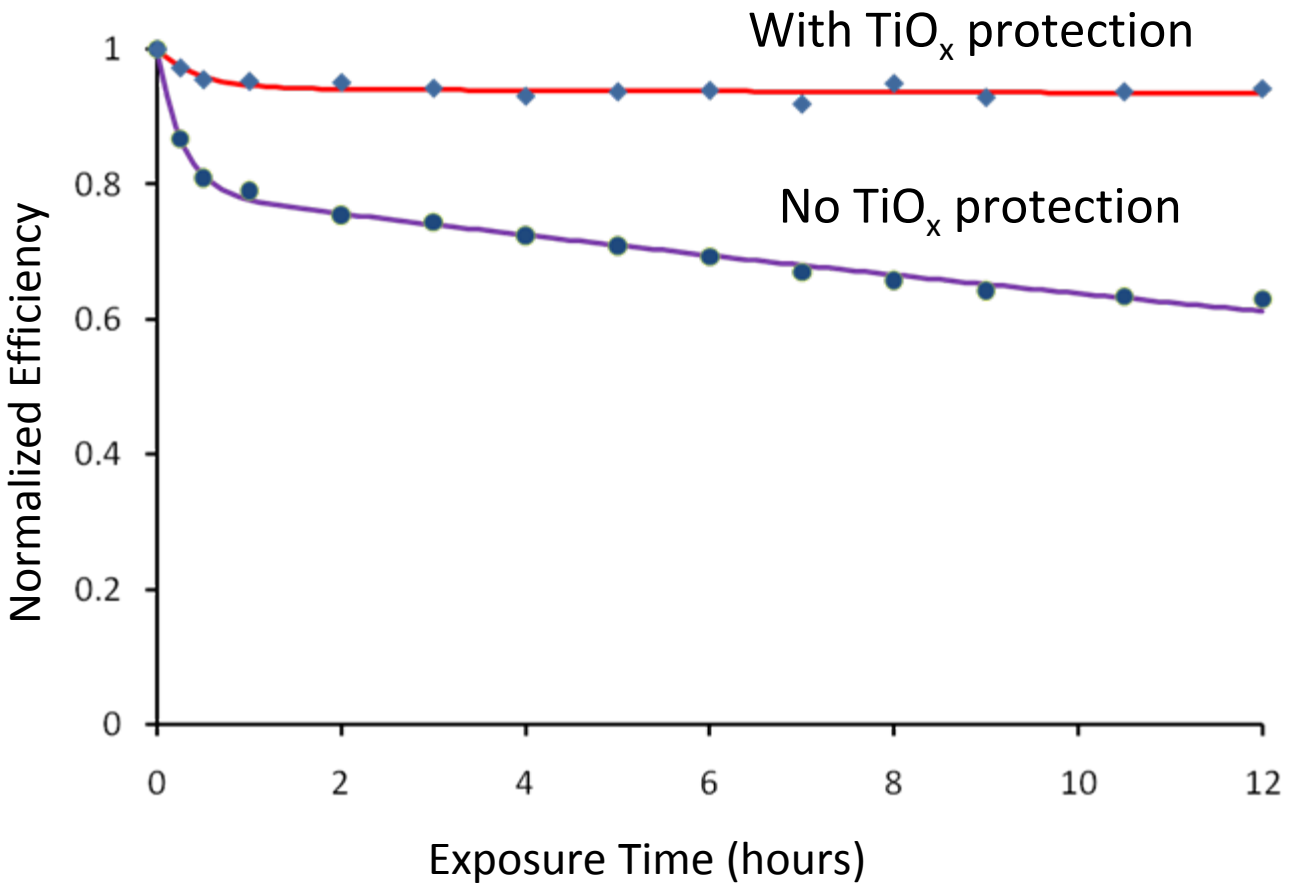
- Oxygen effect



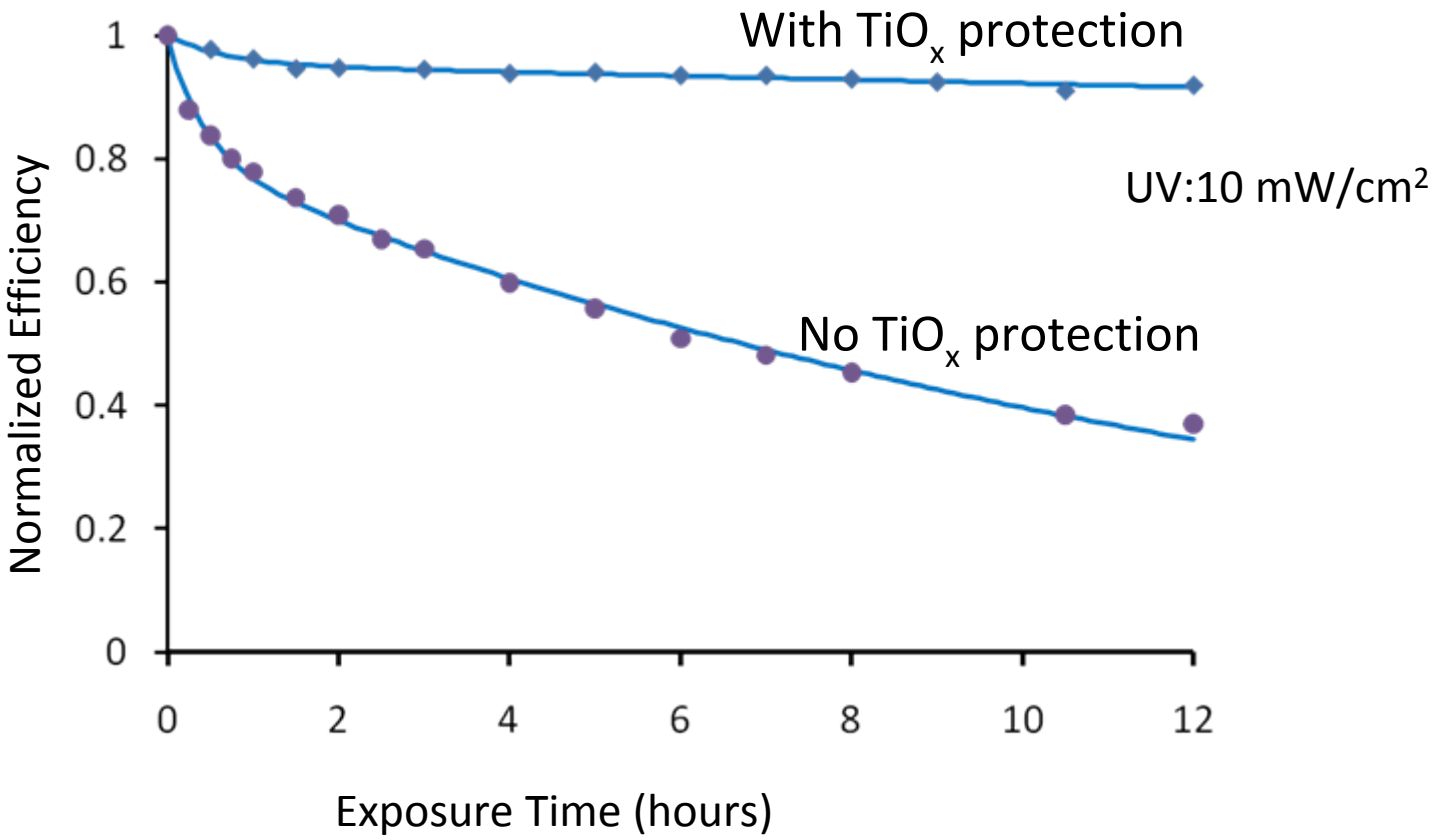
Degradation in N_2

- UV effect

UV:10 mW/cm^2

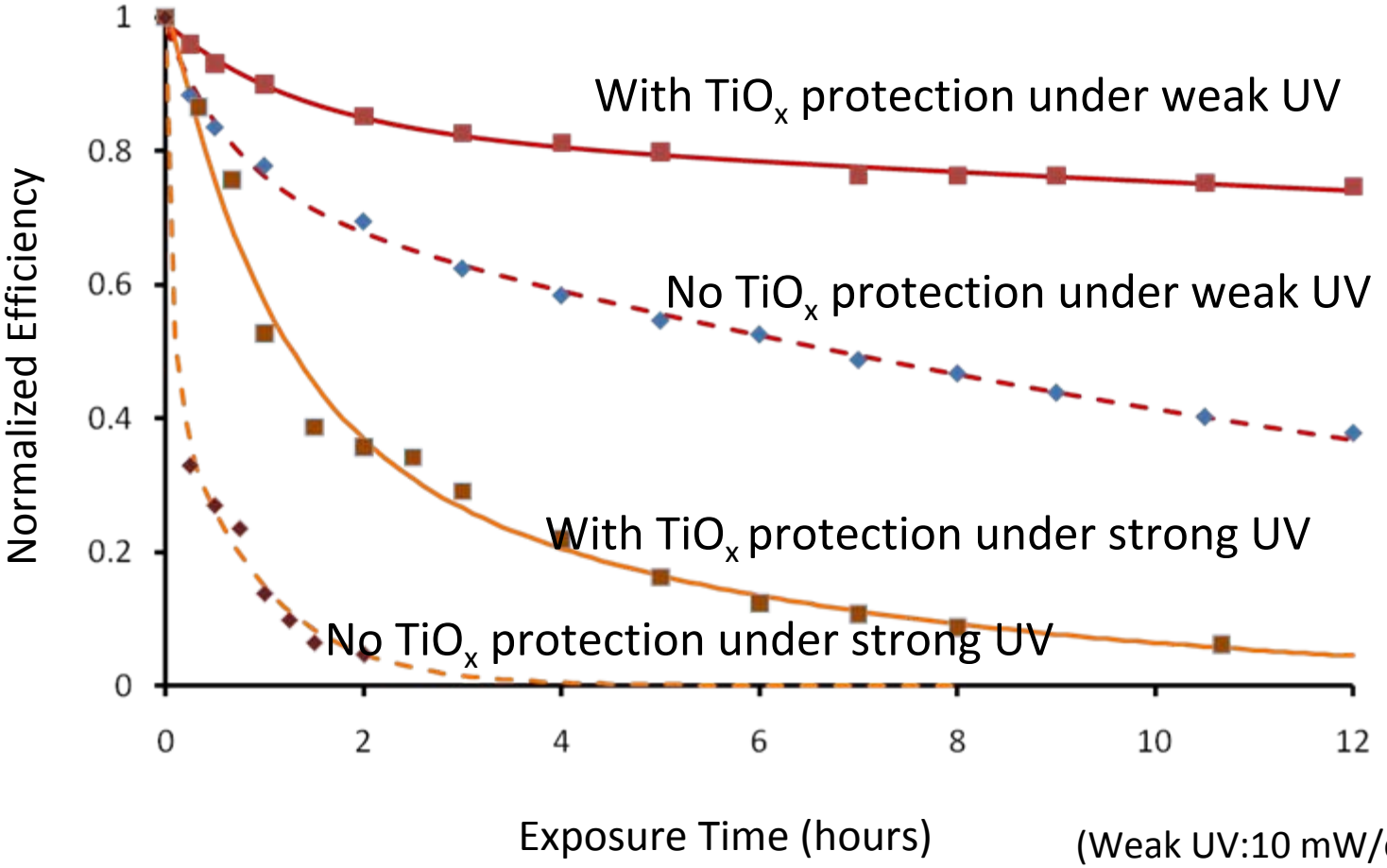


Degradation under combined effect of UV and oxygen exposure



Degradation in O_2

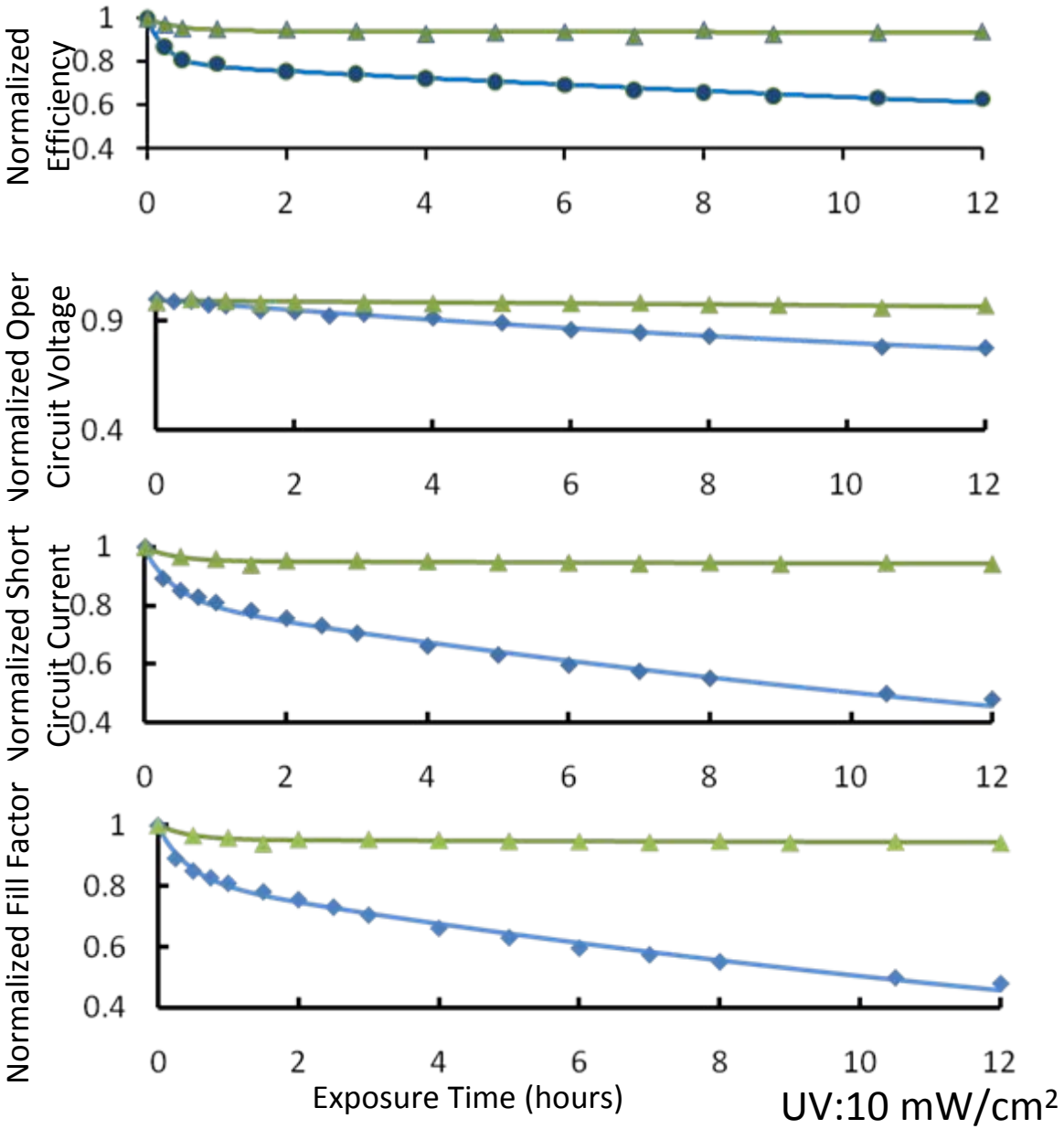
UV intensity effects



(Weak UV:10 mW/cm^2
strong UV: 300 mW/cm^2)

Photovoltaic characterizations

- Photovoltaic parameters in N_2
  - Similar results in air
  - Major loss due to lowering of the short circuit current and the fill factor



Conclusions

- TiO_x acts as a protection layer
  - TiO_x is activated by UV to absorb O_2 and this process protects polymer from oxygen degradation
- Demonstrated enhanced stability using TiO_x under UV:
  - 30 times improvement

Future work

- New material
  - Optimal TiO_x synthesis
  - Doped TiO_x material
- New characterization technique
  - Electrical properties and mobility
  - Temperature dependence of degradation

Outcomes/ Funding support

- **Outcomes**:
  - Developed collaboration with Professor Alan J. Heeger (Nobel prize winner) at UC Santa Barbara
  - Two scientific publications Submitted
    - J. Li, M. C. Gupta, S. Edington, J. T. Yates, Jr, S. Cho, K. Lee and A. J. Heeger, "A Study of Stabilization of P3HT/PCBM Organic Solar Cells by TiO_x Layer"
    - S. Kim, S. Edington, M. C. Gupta, J. Nedy, J.T. Yates, Jr, S. Cho, K. Lee and A. J. Heeger, "Photochemically Activated TiOx Sol-Gel Film-Observation of Oxygen Gas Removal Using a Built-in Organic Scavenger Functionality "
  - Graduate student supported-J. Li
- **Funding support**
  - Proposed to NSF
  - Thank nanoSTAR, the Institute for Nanoscale and Quantum Scientific and Technological Advanced Research at the University of Virginia for their financial support